August 1955 ARS-81-2

United States Department of Agriculture
Agricultural Research Service

HYDRAULIC DRIVE SYSTEM FOR OPERATING DISPERSAL EQUIPMENT IN AGRICULTURAL AIRCRAFT

By Arthur Gieser, Donald Whittam, and Kenneth Messenger
Plant Pest Control Branch

A hydraulic drive system consisting of a few small, light-weight units has been found to be a readily controllable, efficient, and powerful device for operating spray pumps, hopper agitators, and other dispersal mechanisms. Adaptable to any aircraft powered with an engine having an accessory pad for mounting a hydraulic pump, it overcomes some of the disadvantages of other types of drives, such as wood or metal windmills (wind-driven propellers), vee-belt drives deriving power from the aircraft engine, and drives in which the spray pump is attached directly to the engine.

This system can be assembled economically from surplus aircraft accessories. The use of aircraft parts, because of their high quality, serves to assure that the system described -- if properly constructed and not overloaded -- will give many hours of trouble-free service.

Wind-driven systems, although most common, usually become cumbersome when the windmill-propeller is sufficiently large to develop the power required to drive a high-output spray pump. They are sometimes inefficient and create considerable drag. Blades have been known to break, if not properly reinforced, resulting in damage to the equipment or aircraft. Unless equipped with a brake, the pump is driven continuously during flight, causing unnecessary wear of the pump parts.

Spray pumps driven by belts or attached to the aircraft engine run continuously unless provided with a clutch. A centrifugal pump may lose its prime when mounted on the engine, as at this location it may not be sufficiently below the spray fluid level to prime properly. Furthermore, when using flammable spray liquids, a spray pump located between the engine and the firewall may present a fire hazard if leaks occur at the pump packing or hose connections.

The hydraulic system can be turned on or off and its operating speed controlled from the cockpit. A maximum of approximately 7 hp and driveshaft speed of 5000 rpm are available with the proper combination of hydraulic pump and motor. Such a system provides a connection between the aircraft engine and the spray pump that is easily routed through the aircraft structure permitting the pump to be located where desired. Briefly, it does the work of the clutch, transmission, and driveshaft of common automotive systems.

Hydraulic Drive System

The units required for the hydraulic drive system (see diagram) are a piston-type hydraulic pump (1), a piston-type hydraulic motor (2), a reservoir (3), with proper vent (4), a manifold (5), a pressure gauge (6), a conventional relief valve or unloader type of relief valve (7), an on-off valve, cockpit controlled (8), an accumulator (9), a speed control valve (10), and a supply of tubing and fittings suitable for hydraulic systems of 2000 psi (pounds per square inch) or more.

All parts, unless shop made, are available from supply houses handling surplus aircraft accessories or may be purchased new. The hydraulic pump, motor, and pressure relief valves used and referred to in this paper are Vickers aircraft type. However, units having the same physical characteristics and performance, manufactured by other firms, should be entirely satisfactory. 1/

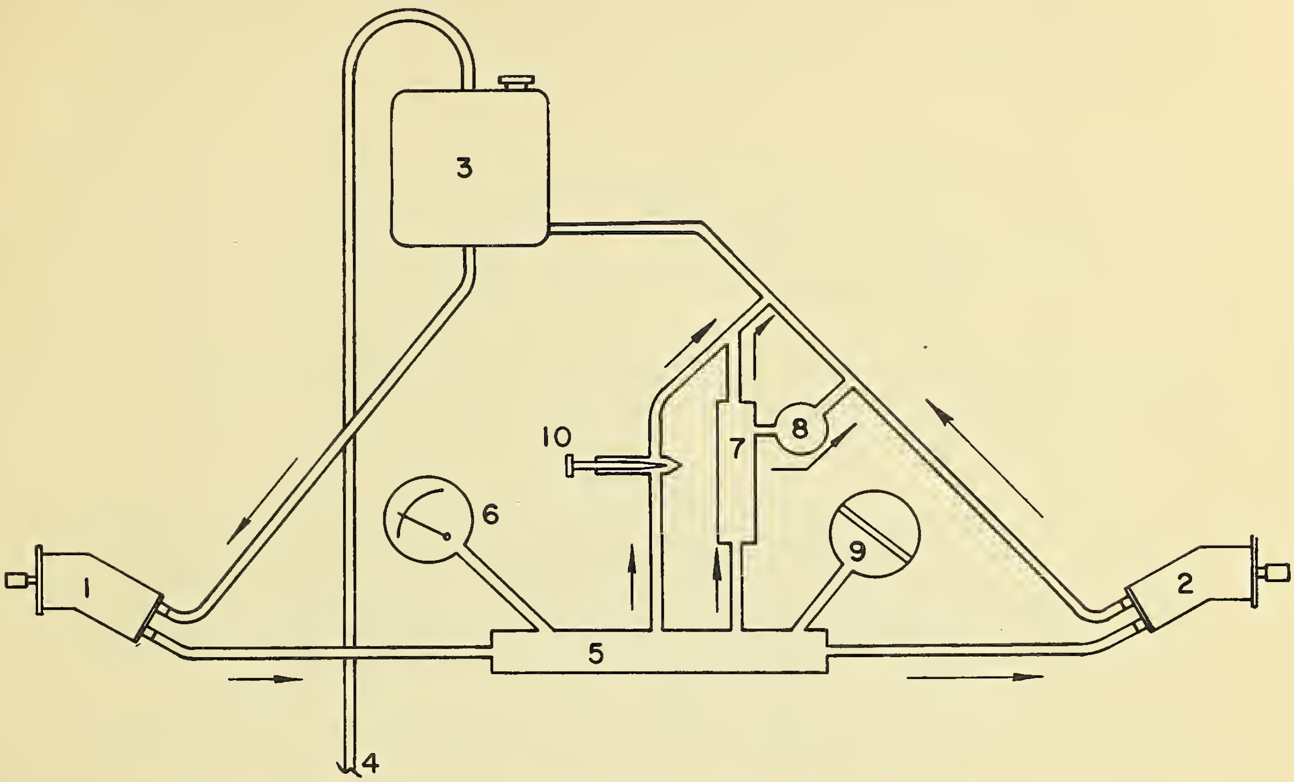
Hydraulic Piston-type Pump

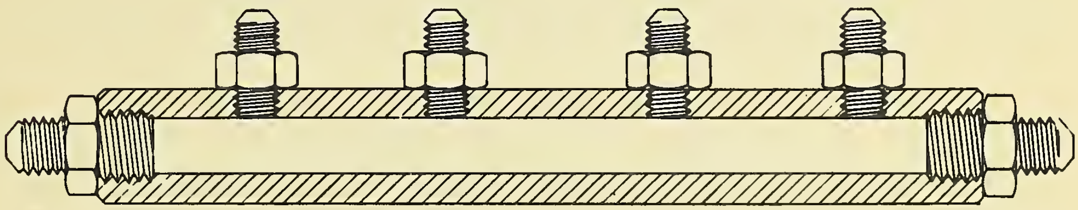
Hydraulic piston-type pumps are manufactured with several different displacements per revolution. The displacement is determined by the angle built into the pump between the pump shaft and the cylinder block. The displacement is in direct relation to the angle and both are usually shown somewhere on the pump body. For example:

Pump angle, in degrees	10	15	20	25	30
Displacement, in cu. in. per rev.	.210	.310	.410	.507	.610

1/ Mention of manufacturers does not constitute endorsement of their products by the U. S. Department of Agriculture.

HYDRAULIC DRIVE SYSTEM





MANIFOLD DETAIL — MAKE FROM 1" O.D. ALUMINUM TUBE WITH $\frac{1}{4}$" WALL THICKNESS — OR — 1" SHAFT BORED TO $\frac{1}{2}$" I.D.

1. HYDRAULIC PUMP
2. HYDRAULIC MOTOR
3. RESERVOIR, 2 GAL. CAP.
4. VENT, ROUTED THRU BELLY
5. MANIFOLD
6. PRESSURE GAUGE, MAY BE ATTACHED WHILE ADJUSTING RELIEF VALVE
7. PRESSURE RELIEF and UNLOADER VALVE 900 psi.
8. ON-OFF VALVE, CONTROLLABLE FROM COCKPIT.
9. ACCUMULATOR - 50 to 60 psi. AIR PRESSURE.
10. SPEED CONTROL VALVE, SHARP NEEDLE VALVE, CONTROLLABLE FROM COCKPIT, IF DESIRABLE TO REGULATE MOTOR SPEED.

Pumps and their angles can be identified by their model number. For instance, in Model PF2713-25-BC, the "P" indicates that it is a pump (rather than a motor) and the "25" indicates the angle is 25 degrees. The cubic inch displacement shown on this pump would be 507 per revolution.

Pump inlet and outlet ports are usually marked and an arrow on a detachable plate shows the required direction of rotation. However, if the rotation must be reversed, because the engine drive turns opposite to the indicated pump rotation, this can be done by removing the head that contains the inlet-outlet ports and rotating it 180 degrees. Should this be necessary, it is recommended that the manufacturer's service-manual instructions be followed. If this manual is not available, the following instructions should permit an experienced mechanic to make the adjustment.

First, it is imperative that before the four nuts that hold the pump head are loosened, the 1/8-inch pipe plug in the head and the small steel pin visible in the plug hole be removed. After the nuts are removed and as the pump head is parted from the pump body, insert a thin finger of metal between these parts and hold the cylinder barrel from moving out of the pump body. The head can then be lifted, enough to clear the stud ends, and rotated 180 degrees. Extreme care should be taken in making this change to prevent the piston cylinder barrel from moving out of the pump body. If this is allowed to happen, pistons will be drawn from their cylinders and difficulty will be experienced in replacing them.

When the head is again close to the body, the metal finger may be removed, the nuts tightened, and the small steel pin and pipe plug replaced. Notches and pegs on the arrow plate and pump head insure that the arrow indicates the correct direction of rotation when the plate is replaced.

To provide an adequate flow of hydraulic fluid through the system, it is recommended that the pump -- the unit mounted on the aircraft engine -- have an angle of 25 or 30 degrees.

Hydraulic Piston-type Motor

A piston-type hydraulic motor is basically the same as a piston-type pump although, in actual operation, the pump receives rotary power from the aircraft engine and translates it into hydraulic pressure whereas the motor receives this pressure and translates it into

rotary power. Motors can be distinguished from pumps by the model number. The "PF" on the pump becomes "MF" on the motor. A motor may be operated in either direction merely by reversing the inlet and outlet lines since the head containing the inlet-outlet ports is somewhat different than the head on a pump and does not need to be rotated.

Piston-type pumps may be used as motors. However, if it is necessary to reverse their rotation, the procedure described under "pumps" should be carefully followed. The use of a motor as a pump is not recommended.

A small bleed-hole on the motor body near the mounting flange is stopped with a 1/8-inch pipe plug. This plug must be removed to prevent pressure from building up in the motor housing and consequent damage to the shaft seal. From the bleed-hole a vent line should be run to the return line from the motor. If the bleed-hole is not so vented, the hydraulic fluid will be lost through seepage, eventually causing the system to run dry. This may result in damage to both the pump and the motor.

When a pump and motor of the same displacements are used, the speed of the motor will be approximately that of the pump if no fluid is by-passed from the pressure line between the two. However, when dissimilar displacement units are used, the speed ratio is in direct proportion to the displacements, as illustrated by the following example.

The hydraulic pump drive on a P&W R-985 aircraft engine turns 1 1/2 times the crankshaft speed. Therefore at an engine rpm of 2000, the hydraulic pump will be driven 3000 rpm. If a 25-degree angle pump (.507 cu. in. per rev.) is operated at 3000 rpm, the following motors will perform as shown:

Motor angle, in degrees	10	15	20	25
Displacement, cu. in. per rev.	.210	.310	.410	.507
*Motor rpm	7500	4900	3700	3000
Ratio	5-2	5-3	5-4	5-5

* Motor rpm will be slightly less than indicated by the arithmetical ratio as the load on the system is increased.

To determine the proper angle for a pump-and-motor combination, it is first necessary to calculate the revolutions per minute

the hydraulic pump will turn when the aircraft engine is turning at its normal operating speed. The ratio of hydraulic pump drive to crankshaft speed differs on different makes and models of engines. It is also necessary to know the operating speed of the unit the hydraulic motor will drive, in order to determine the proper motor to produce this speed in combination with the pump selected.

Reservoir

A reservoir of at least 2 gallons capacity is required for the hydraulic fluid supply. The fluid level should be carried at 1 1/2 gallons after the system has been filled and purged of air bubbles.

The outlet line should be attached to the bottom of the reservoir and the return line to the side, not higher than a point half way between the top and bottom of the reservoir. The fluid should be maintained well above the return port at all times to prevent foaming. The reservoir should be so installed in the aircraft that the fluid level may be easily checked and fluid added when necessary.

The reservoir must be vented. A vent line extending outside the fuselage is better than a hole in the filler cap.

Tubing

The tubing used to connect the various units of the system should be 1/2 inch outside diameter or larger and capable of withstanding pressures of at least 2000 psi. A 5/8-inch tube should be used between the reservoir and pump. All tubing must be anchored securely and routed as directly as possible. Bends should be of wide radius wherever possible. The use of sharp bends or elbow fittings increases flow resistance and should therefore be used only when necessary.

Hydraulic hoses should be used between the pump and the point where the lines pass through the firewall. Shorter lengths, 6 inches or so, may be used to attach the lines to the motor. Other lines need not be flexible.

Grouping all hydraulic units closely to avoid long lengths of tubing and keeping sharp bends to a minimum will reduce friction and heating, thus increasing the efficiency of the system.

Pressure Relief Valve

To avoid excessive hydraulic pressures that may cause damage, it is advisable to install a pressure relief valve in the system. One adjustable from 350 to 1350 psi that may also be used as an unloader valve is preferred. Relief pressure should be set, while the system is in operation, to a pressure approximately 100 psi above the working pressure of the system. This valve should not be installed directly in the pressure line between the pump and motor, as it may interfere with the free flow of oil in the line. A T-fitting should be used to connect the relief valve to the pressure line. The outlet port of the relief valve may be connected to the return line from the motor or piped directly to the reservoir. If the by-passed fluid is piped directly into the reservoir, the flow should enter below the fluid level as does the return flow from the motor.

Any aircraft hydraulic system unloader-type valve, similar to the Vickers Model AA-11501, offering the desired pressure adjustment range, may be used. An "on-off" valve can be used to unload this valve. If the unloader valve can be attached conveniently to the reservoir and the "on-off" valve attached to it, plumbing will be kept to a minimum. The "on-off" valve can be controlled remotely from the cockpit by a push-pull or cable-and-spring control; or if the aircraft has an electrical system, an electric solenoid valve may be used.

There are several reasons for using an unloader type of relief valve:

Unloading the system stops the hydraulic motor and makes the hydraulic pressure negligible throughout the system.

The system is permitted to cool in the unloaded condition, thus reducing operating temperatures.

Wear of parts in units driven by the system is reduced.

In the unloaded condition, the system takes no appreciable power from the aircraft engine. This is especially desirable during take-off.

Accumulator

When an unloader type of relief valve is used to start and stop the hydraulic motor, an accumulator surge chamber should be used

in the system. Hydraulic pumps and motors are positive displacement types. Therefore, without an accumulator to absorb the initial surge when the system is loaded, the motor must reach its operating speed almost instantly. Under such a condition the pump driveshaft may shear or other attached equipment may be damaged. An accumulator 5 inches in diameter, pressurized with air to 55 psi will provide gentle and smooth operation when starting the hydraulic motor. The accumulator should be connected to the pressure side of the system. A T-fitting in the pressure line to the relief valve will provide a suitable connection.

Pressure Gauge

A pressure gauge capable of withstanding 2000 psi will be required to adjust the relief valve. Once the valve has been adjusted to the desired pressure, the gauge may be removed from the system. However, if it is permanently installed so that it may easily be read by the pilot, it will serve to indicate whether the hydraulic system is functioning properly.

Speed Control

The speed of the hydraulic motor can be controlled with a needle valve. A valve having a long minimum-taper needle is desirable as it is easily adjusted and insensitive to small degrees of movement.

The needle valve should be located between the pressure line and the return line. Maximum motor speed is obtained with the needle valve in the closed position. As the valve is opened, fluid bleeds off and the motor speed is reduced.

Manifold

A convenient way to connect the relief valve, accumulator, pressure gauge, and needle valve to the pressure line is to use a manifold (see diagram) having sufficient bore to prevent serious restriction of fluid flow.

A satisfactory manifold is approximately 8 inches long, made of 1-inch outside diameter aluminum tubing with 1/4-inch wall thickness. It can also be made by boring a 1/2-inch hole lengthwise through a 1-inch outside diameter aluminum rod. Holes can be drilled and tapped for appropriate nipples in the side of the tube for outlets to relief valve, accumulator, pressure gauge, and needle valve. The ends of the bore can be tapped for nipples to connect the pressure lines.